The Boeing Company
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December 9, 2005
107E-6054-05

Ms. Jill Bruss
Missouri Department of Natural Resources
Hazardous Waste Program, Permits Section
P.O. Box176
Jefferson City, MO 65102

BOEING

Encl: REVISED TPH SOIL VAPOR SAMPLING WORK PLAN, BOEING TRACT I, HAZELWOOD, MISSOURI

Dear Ms. Bruss:

In a previous letter to you, dated July 22, 2005, we requested that due to revisions that may be required to the Risk Based Corrective Action Report, submittal of a revised Soil Vapor Work Plan will be delayed until we receive comments to that report. We have received your comments to the Risk Based Corrective Action Report and have responded to those comments in draft form. Although it is unclear at this time how changes to the RBCA Report may affect the indoor inhalation risk calculations associated with TPH, we are submitting a revised TPH Soil Vapor Sampling Work Plan for your approval.

The enclosed work plan has been revised as follows to address each comment submitted in your letter of June 15, 2005:

1) Two sampling events have been included in Section 2.3, one in the winter and one in the summer.

2) Permanent soil vapor sampling wells have been specified in Section 3.2.

3) The plan specifies in Section 3.3 that sampling will not be conducted for at least 30 minutes following probe installation.

4) The placement of a regulated flow meter between the probe and the sample container to measure the flow rate has been specified in Section 3.4.2.

5) Purge volume has been changed in Section 3.3 to at least three volumes of the full sampling system.

TPH Soil Vapor Sampling Work Plan
Boeing Tract 1
Hazelwood, Missouri

Prepared for:
The Boeing Company
St. Louis, Missouri

Prepared by:
MACTEC Engineering and Consulting, Inc.
3199 Riverport Tech Center Drive
St. Louis, Missouri 63043

MACTEC Project Number 3250035046.12

December 5, 2005

6) Section 3.4.4 specifies that soil gas sampling will not be conducted within 48 hours of a significant precipitation event.

7) The collection of one field duplicate sample per sampling event or one per twenty samples, whichever is greater is specified in Section 3.4.6. This section also states that at least one equipment blank will be collected per sampling event or per 25 samples, whichever is greater.

BOEING

Our intention is to immediately proceed with the soil vapor sampling process following your approval of the work plan. Please contact me if you have any questions.

Sincerely,

Joseph W. Haake, Group Manager
Environmental and Hazardous Materials Services
Dept. 107E, Bldg. 111, Mailcode S111-2491
(314) 777-9181

cc: Mr. Rich Nussbaum, MDNR, HWP, Permits Section
Ms. Christine Kump-Mitchell, MDNR, HWP, Permits Section, SLRO
Ms. Stephanie Doolan, U.S. EPA, Region VII
Ms. Joletta Golik, Airport Authority

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Appendices

1.0 Purpose and Objective

A Resource Conservation and Recovery Act (RCRA) Facility Investigation [(RFI) MACTEC, 2004] has recently been completed at the Boeing Tract 1 facility (Facility) located in Hazelwood, Missouri (Figure 1-1). Soil borings, temporary piezometers and groundwater monitoring wells were installed at the Facility as part of the RFI to characterize the nature of any hazardous waste/constituent releases to soil or groundwater. Soil and groundwater samples were collected and selectively analyzed for volatile organic compounds (VOCs), total petroleum hydrocarbons (TPH), semi-volatile organic compounds (SVOCs), polychlorinated biphenyls (PCBs) and total metals.

Following completion of the RFI, an assessment was conducted by Risk Assessment & Management Group Inc. (RAM Group) utilizing the RFI and other historical data and the Missouri Risk-Based Corrective Action (MRBCA) process. Based on this assessment, there was the potential for exceedence of acceptable risk at selected locations at the Facility (*Risk-Based Corrective Action Report, Boeing Tract 1*, September 2004).

For risk assessment purposes the site was divided into exposure units (nine Areas and 18 Sub-areas) based on the current and future land use and activity patterns (Figure 1-1). The intent of the exposure units was to define portions of the Facility that are relatively homogeneous in terms of risk and exposure factors and to develop target levels for each exposure unit consistent with the land use and/or other characteristics to the exposure condition of the Area.

At nine exposure units the risk assessment indicated that there was a potential for exposure to TPH diesel range organics (DRO); and/or oil range organics (ORO) by indoor inhalation from groundwater by a non-residential worker. Sub-area (3C) additionally exceeded the risk for total TPH by outdoor inhalation from groundwater by a construction worker. Because these exceedences are primarily attributed to the very conservative models (Johnson and Ettinger, Jury et al, and Cowherd) used to estimate the indoor and outdoor inhalation vapor intrusion risk, soil vapor sampling was recommended as a better estimator of vapor risk. Per the MRBCA process, the field collected soil vapor data will be utilized to recalculate the risk, in lieu of the values calculated by the models from the soil and groundwater data.

One of the nine exposure units that exceeded the risk for TPH is impacted as the result of off-site contamination; interim measures consisting of soil removal are planned at four others. Soil vapor sampling is proposed at the remaining four units (Risk Sub-areas 2B, 3C, 3G, and 6C).

Soil vapor sampling is needed to determine actual constituents of concern (COCs) concentrations to better estimate potential vapor intrusion into buildings and associated health risk to the building occupants. The results of this evaluation may indicate the absence of unacceptable health risk due to vapor intrusion.

Vapor samples will be analyzed for TPH and benzene, toluene, ethylbenzene, xylenes (BTEX), methyl tertiary-butyl ether (MTBE), and naphthalene. Additionally the vapor samples will be analyzed for the volatile COCs identified in the Risk Assessment for each Sub-area. Table 1-1 provides a listing of the COCs for each Sub-area.

2.0 Soil Vapor Sampling

2.1 Locations

TPH soil vapor sampling locations were determined by selecting the RFI groundwater sampling locations that contained the highest TPH concentrations for each Sub-area where a risk exceedence was calculated. A total of 14 sampling points were selected for the collection of soil vapor samples. These sampling points represent the highest TPH concentrations for each Risk Sub-area. Summaries of the boring locations selected are presented below and are marked on Figures 2-1 through 2-4.

- **Risk Area 2B:**
  - TP-7
  - TP-9
  - TP-15
  - TP-16
- **Risk Area 3C:**
  - B42W1
  - B42S5
  - B45S8
  - B45S11
- **Risk Area 3G:**
  - Two locations in the vicinity of B2S2
- **Risk Area 6C:**
  - Two locations in the vicinity of B27E2
  - Two locations in the vicinity of B27I9

2.2 Depth

Soil vapor samples will be collected approximately one foot above the capillary fringe, with a minimum collection depth of three feet below ground surface (bgs). If the depth to groundwater is less than five feet bgs, one sample will be collected from each location, if groundwater is greater than five feet bgs, two vapor samples will be collected from each location. Soil gas sampling depths will be consistent from sampling point to sampling point. Groundwater depth will be determined by inspection of soil cores by the field geologist assisted by the measurement of groundwater at the nearest monitoring well to the sampling location. Historical groundwater depths for the nearest wells to the proposed sampling locations are presented in Table 2-1.

2.3 Frequency

The historical groundwater elevation data (Table 2-1) indicates that over a two year period the groundwater fluctuated three feet or less. Based on the constancy of the groundwater levels, soil vapor sampling will be conducted in two sampling events, unless the data fluctuates greatly in which case

additional sampling will be conducted. The sampling events are proposed to occur in the winter of 2005 (cold season) and the summer 2006 (warm season).

3.0 Soil Gas Measurement Techniques

Soil vapor sampling will follow the Standard Operating Procedures (SOP) for Soil Vapor Grab Sampling Activities Using the Geoprobe® Post-Run Tubing (PRT) System With 6-Liter SUMMA® Canisters and National Institute for Occupational Safety and Health (NIOSH) Tubes (RAM, 2004a). Soil vapor samples are collected in six-Liter SUMMA® canisters and NIOSH tubes utilizing Geoprobe® direct-push boring methodologies and the PRT system. The target soil vapor sampling depth will be determined prior to sampling at each location as determined in Section 2.3 of the SOP. Optional field measurements for biogenic gases, such as oxygen, carbon dioxide, and methane, may be collected from each sampling location using a handheld landfill gas meter.

3.1 Preparation

Prior to mobilization, MACTEC personnel will make all necessary preparations for the work. The preparations will include:

- Determine equipment accessibility to each sampling location,
- Coordinate schedule with subcontractors, property owner(s), regulatory agencies, and the laboratory,
- Obtain all necessary field equipment and materials, and
- Verify that all necessary field equipment and materials were received and are properly operating. Refer to Appendix A (Guide to Air Sampling and Analysis, Air Toxics Ltd.) Section 2.3.2 before mobilization.

3.2 Direct-Push Geoprobe® Boring and Soil Gas Implant Installation

This section describes the field methodology that will be utilized to install permanent soil vapor sampling wells to be utilized to collect the soil vapor samples. Because of site-specific conditions or obstacles, the sampling plan may be modified as needed, based on the professional judgment of the MACTEC field personnel.

MACTEC will utilize a Geoprobe® contractor to provide and operate the Geoprobe® rig and Geoprobe® equipment. The equipment will be positioned at the sampling location and the drive rod and expendable point will be advanced into the subsurface. Geoprobe® implants are constructed of double woven stainless steel wire screen that is six-inches in length. The implant is connected to 0.25-inch Teflon tubing and will be placed midway between the top and bottom of the desired sampling interval. Once the target sampling depth has been achieved, the rod is pulled up about 12 inches to allow the expendable point to be released and void space is created. Sand pack will be placed around the implant through the rods, extending six inches above the implant. The grain size of the sand pack should be appropriately

sized (for example, no smaller than the adjacent formation) and installed to minimize disruption of airflow to the sampling tip. At least one foot of dry granular bentonite will be placed on top of the sand pack to preclude the infiltration of hydrated bentonite grout into the sand pack. The borehole will then be grouted with a neat cement to the surface. Detailed information for the implant system is provided in Appendix B (Geoprobe® Sampling Implant Operation).

Surface completion will consist of a flush mount well box set in concrete. The tubing will be fitted with a gas tight fitting and will be labeled for identification.

3.3 Soil Gas Probe Equilibration and Purging

During probe installation, subsurface conditions are unavoidably disturbed. The subsurface soil gas profile should be allowed to equilibrate following this disturbance. To allow for equilibration, soil gas sampling will not be conducted for at least 30 minutes following probe installation.

Prior to sampling, soil gas sampling probes will be purged to ensure that stagnant or ambient air is removed from the sampling system and to assure samples collected are representative of subsurface conditions. The following purge procedure will be used:

- Calculate the volume of the sampling system by summing the volume of the probe screened interval (including filter pack void space, accounting for porosity of sand pack), the volume of tubing from the probe tip to the ground surface, and the volume of above ground tubing connecting the soil probe to the sample collection device.
- Purge the monitoring point until at least three volumes of the full sampling system have been evacuated. Purging should be conducted at flow rates and vacuum conditions similar to those for sample collection (described below).
- If the soil matrix is such that purging as recommended above is not possible due to low or no flow conditions (i.e., gas will not flow or flow is severely restricted), the probe should be advanced deeper to look for zones of higher permeability. If the deeper probe does not encounter a higher permeability zone and low or no flow conditions persist, the probe should be abandoned and a new probe advanced elsewhere on the site.

3.4 Soil Gas Sample Collection Procedures

3.4.1 Sample Containers

- Samples will be collected in Summa canisters.
- The analytical laboratory will supply the sample containers and will certify that all sample containers supplied by them are free of contaminants at concentrations exceeding contaminant detection levels.

3.4.2 Sampling Flow Rate

- An initial sampling rate of 200 milliliters per minute (mL/min) or less is recommended.

- A regulated flow meter should be placed between the probe and the sample container to control and measure the flow rate.
- The sampling rate may be modified based on specific field conditions, including the vacuum observed. Data for samples collected at a flow rate exceeding the recommended rate of 200 mL/min shall be flagged in the final report. Flagged data will not necessarily reject, flagging is intended to facilitate a more thorough review of the data.

3.4.3 Vacuum Conditions

- To measure sample collection vacuum, a vacuum gauge must be placed between the probe and the sample container. MDNR recommends a sampling vacuum of less than 100 inches of water. Note, however, that, when using a Summa canister, the vacuum gauge reading is dominated by the vacuum in the canister and does not reflect the vacuum at the probe tip. Therefore, with a canister, the vacuum gauge reading becomes meaningless as does data flagging discussed below.
- To achieve the target sampling vacuum, the sampling flow rate should be adjusted using the flow regulator.
- If the sampling vacuum exceeds 100 inches of water, and a reduction in the sampling flow rate does not reduce the vacuum, continue to attempt to collect the sample, recording flow rate and vacuum conditions. Data for samples collected under a vacuum of greater than 100 inches of water must be flagged. Flagged data will not necessarily be rejected or considered suspect, flagging will simply facilitate a more thorough review of the data.
- If the sample container cannot be filled within an expected time frame, such time being dependent on the size and type of the sample container and sampling equipment (e.g., tube diameter), discontinue sampling and document vacuum observations. Generally, data from samples collected under such conditions will not be valid.

3.4.4 Field Conditions

- Soil gas sampling will not be conducted within 48 hours of a significant precipitation event (for example, 0.5 inch or greater of rain) or comparable on-site watering.

3.4.5 Sample Collection

- Aboveground sampling equipment consists of connector tubing, regulated flow meter, pressure gauge, and purging equipment.
- Connect aboveground sampling equipment to probe at the surface. Check all sampling system connections and fittings for tightness and obvious deterioration.
- Quick connect fittings and nylon tubing should be used to ensure vacuum tightness of the system and that chemicals in the air stream are not reacting with or adsorbing to the tubing. Compression fittings should be avoided for all connections except at the Summa canister.
- Purge at least three volumes of air from the sampling system as described in Section 3.3.

After purging is complete, close the valve to the purge line and/or disconnect purge apparatus, as appropriate.

- Connect the sample container to the sampling line, using quick-connect, airtight fittings.
- Follow the leak test procedures described in Section 3.5, below.
- Open valve and collect sample into sample container, following the sample flow rate and vacuum guidelines discussed above. During sampling, measure and record sample flow rate and vacuum every two to five minutes.
- Disconnect sample container and immediately label the container with sample identification information.
- If Summa canisters are used, measure the final pressure of the canister using a pressure gauge. Record the final canister pressure.
- Store sample containers out of direct sunlight, and do not chill.

3.4.6 Quality Control Samples

- One field duplicate will be collected per sampling event or one per twenty samples, whichever is greater.
- Duplicate samples shall be collected in separate sample containers, using the same procedures and at the same location and depth as the original sample.
- Preferably, duplicate samples should be collected simultaneous to collection of the primary sample using a sampling tee. Alternatively, the duplicate may be collected immediately after the collection of the primary sample.
- At least one equipment blank will be collected per sampling event or per 25 samples, whichever is greater.

3.5 Leak Testing

3.5.1 Requirements

- Leakage during soil gas sampling may dilute samples with ambient air and produce results that underestimate actual site concentrations or contaminate the sample with external contaminants. Therefore, a leak test will be conducted each time a soil gas sample is collected to determine whether leakage has occurred.
- For each sample, use a hand pump to vacuum test the sampling equipment after assembly.
- A leak check, or tracer, compound such as isopropanol will be used to determine if leaks are present.
- Immediately before sampling, place the leak check compound at each location where ambient air could enter the sampling system or where cross contamination may occur. For liquid compounds (for example, isopropanol), wet a paper towel with the leak check compound and place the towel over each location where ambient air could enter the sampling system. These areas include: the base of the soil probe at ground surface, the connection from the soil gas probe to the sampling line, and any connections within the sampling line.

- The leak check compound will be included in the list of analytes looked for during laboratory analysis of each sample.

3.5.2 Detection of leak check compound

- If greater than 100 ug/L of the leak check compound is detected in a sample, the following actions will be taken:
  - Review the analytical results that show a detection of the leak check compound.
  - If a review of the data indicates that the analytical data is accurate, the cause of the leak through system testing will be evaluated.
  - Based on the concentration of the leak check compound detected, the impacts of the leak on sample collection and sample integrity will be evaluated and documented in the soil gas investigation report.
  - In certain cases, data in which a leak check compound has been detected at a concentration in excess of 100 ug/m3 may be rejected. In such cases, resampling may be required.

3.6 Field Documentation

At a minimum, the following information will be recorded in the field logbook for each soil vapor sample collected:

- Ambient air temperature;
- Sample ID – will consist of the previous Soil Boring Location ID and SV 01-10.5. This will designate it as a soil vapor sample collected at a depth of 10.5 feet at that previous soil boring ID location. The depth will be rounded to the nearest 0.5 foot;
- Sample depth (with calculations if boring is performed at an angle);
- Sample location with schematic showing at least two measurements to fixed site features,
- Sample date (e.g. mm/dd/yy - 09/21/02);
- Sample time in 24-hour format (e.g. 13:50 for 1:50 in the afternoon);
- Length of sampling time;
- Beginning and ending canister pressure; and
- For NIOSH tube sampling, the flow rate and length of sampling time.

3.7 Soil Chemistry and Geotechnical Parameter Samples

Subsurface soil samples will be collected continuously from the surface to the capillary fringe (determined by the field Geologist) in an adjacent boring to those used to obtain soil vapor samples using a Geoprobe Macro Sampler. A soil sample from each boring corresponding to the depth of the vapor sampling location will be split, and half analyzed for chemical parameters and the other half analyzed for geotechnical parameters to assist in the evaluation of the soil vapor results.

Soil samples from Areas 2B and 6C will be analyzed for VOCs, MTBE, naphthalene, TPH-GRO (gasoline range), and TPH-DRO (diesel range). At Areas 3C and 3G, the soil samples will be analyzed for BTEX, MTBE, naphthalene, TPH-GRO, and TPH-DRO.

The split samples will be analyzed for the following geotechnical parameters; Volumetric Water/Moisture Content, and Fractional Organic Carbon.

4.0 Laboratory Analysis Procedures

The SUMMA® canisters and NIOSH tubes will be prepared for sampling by the certified laboratory selected for laboratory analysis. Prior to sampling, each canister will be cleaned and blanked. Following cleaning and blanking, the canisters will be evacuated, leak-checked, their vacuum measured, and prepared for field deployment.

The soil vapor and background air samples will be analyzed for selected VOCs as specified below following guidance outlined in Environmental Protection Agency (EPA) Methods Modified TO-15 and TO-3, and NIOSH Method 1550.

- BTEX and MTBE – Modified TO-15 (Std. Level),
- Naphthalene – Modified TO-15+Naphthalene (Std. Level),
- TPH gasoline range (C5-C10 or C2-C12) – Modified TO-3 (Std. Level),
- TPH-D (diesel range) – NIOSH 1550, and
- Isopropanol (leak test) – Modified TO-15 (Std. Level).

5.0 Quality Assurance – Quality Control Procedures

Quality Control (QC) on the project will consist of method appropriate laboratory quality control measures run to evaluate the precision and accuracy of the analytical methods. QC for the project field work will consist of performing and documenting equipment/instrument specific calibrations, inspections, and tests to evaluate the equipment precision and accuracy. Additionally, equipment that does not perform to specifications or is defective is taken out of service, clearly identified, and segregated until it has been repaired and shown by calibration/verification to perform satisfactorily. Routine maintenance is performed as needed, depending on how often the equipment/instrument is used, the manufacturer's recommendations, and previous experience.

Quality Assurance (QA) for the project will consist of review of the field data; laboratory data; evaluation of QC problems; coordination with the laboratory or field personnel to answer questions and resolve problems; and technical review of the report.

6.0 Reporting

A. A soil gas investigation report that includes a discussion of field operations, deviations from the approved work plan, data inconsistencies, and other significant procedural and analytical details will be prepared. Analysis of the data will be used to supplement the risk assessment already submitted to the Airport and MDNR following the protocol included in the MRBCA Guidance Document.

B. At a minimum, the soil gas investigation report must contain the following:

- A site plan map, a map identifying soil gas probe locations, and a map showing soil and groundwater contamination relative to the locations of the soil gas probes and any current or future structures.
- A site map on which soil gas concentration data has been plotted. The map must be at the same scale as the maps discussed above.
- A narrative description of probe installation and sampling procedures, including leak check testing.
- Analytical data summary tables.
- Laboratory data sheets.
- A table showing applicable target levels and appropriate documentation showing how the target levels were calculated.
- A narrative discussion of analytical results, including a comparison of soil gas sampling results to soil vapor target levels.
- Legible copies of field forms, logs, and associated notes pertinent to probe installation and soil gas sampling.
- As-built diagrams of probes or wells showing overall construction and depth of each sampling point.
- QA/QC data.
- Conclusions and recommendations.

7.0 References

MACTEC Engineering and Consulting, Inc. (MACTEC). 2004. RCRA Facility Investigation Report for McDonnell Douglas, Hazelwood, Missouri.

MACTEC. 2003. Environmental Field Investigation for Boeing Tract 1 South Property. Hazelwood, Missouri Facility.

Risk Assessment & Management (RAM) Group, Inc. 2004. Risk Based Corrective Action Report for McDonnell Douglas, Hazelwood, Missouri.

RAM Group, Inc. 2004a. Standard Operating Procedures (SOP) for Soil Vapor Grab Sampling Activities Using the Geoprobe® Post-Run Tubing System With 6-Liter SUMMA® Canisters and NIOSH Tubes.

Tables

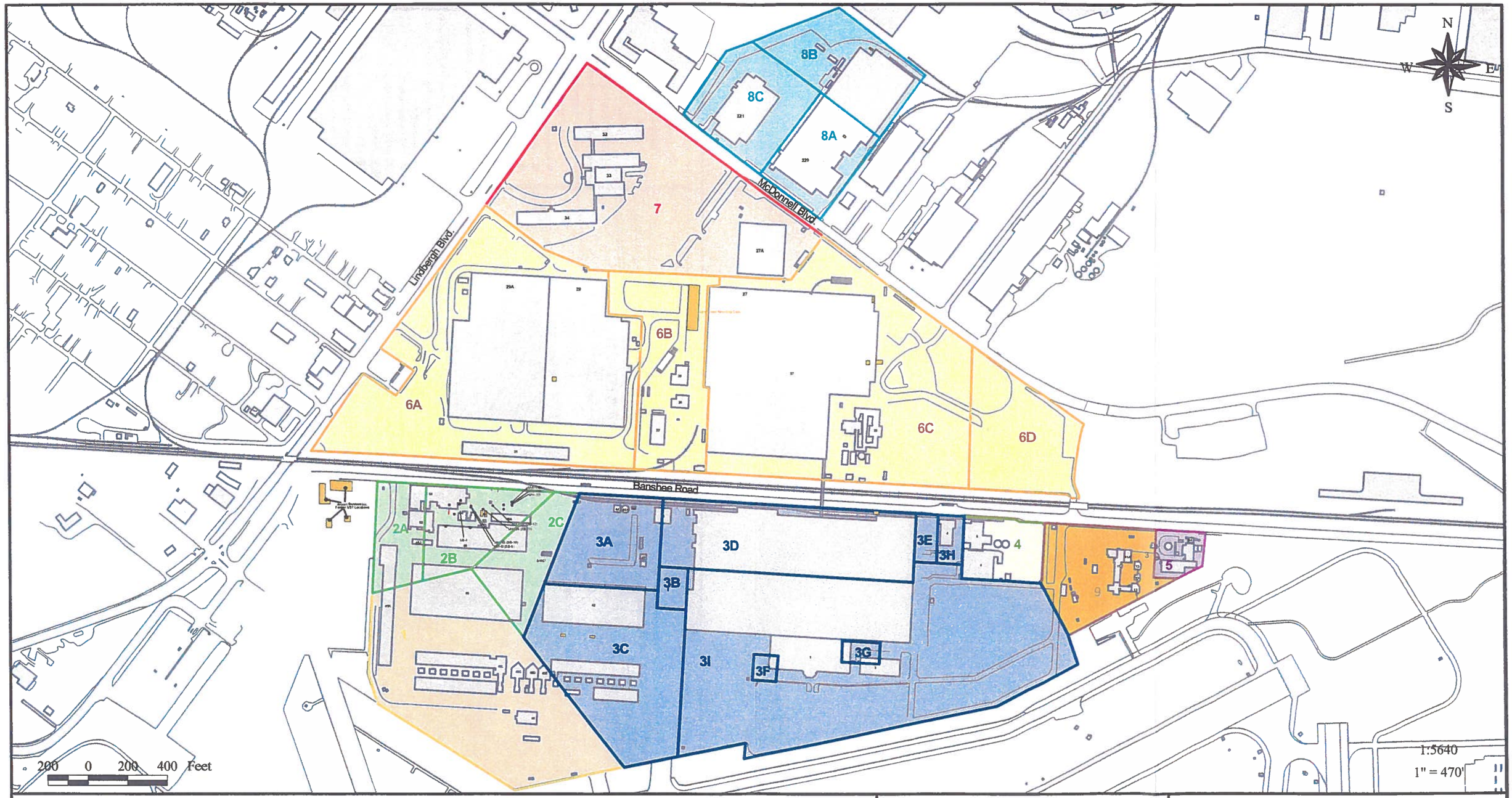
Table 1-1 List of Constituents of Concern for Risk Sub-Areas

Risk Sub-Area	Analytes
All	Benzene
	Ethylbenzene
	Methyl-tert-butyl ether
	Naphthalene
	2-Propanol
	Toluene
	Xylenes
	TPH
2B	Cis-1,2-Dichloroethene
	1,1-Dichloroethene
	n-Butylbenzene
	n-Propylbenzene
	Sec-Butylbenzene
	Tetrachloroethene
	Trans-1,2-Dichloroethene
	Trichloroethene
	1,2,3-Trimethylbenzene
	1,2,4-Trimethylbenzene
	Vinyl Chloride
3C	n-Butylbenzene
	n-Propylbenzene
	Sec-Butylbenzene
3G	1,2,4-Trimethylbenzene
6C	Cis-1,2-Dichloroethene
	2-Hexanone
	Trichloroethene
	Vinyl Chloride

Table 2-1 Historical Depth to Groundwater Measurements, Boeing Tract 1, Hazelwood, Missouri

Risk Area	Well ID	Date	Depth to Water (feet)
2B	MW-11S	2/20/2001	6.22
		7/25/2001	6.67
		10/29/2001	7.57
		12/17/2001	5.39
		3/5/2002	6.58
		6/3/2002	5.62
		8/13/2002	6.19
		8/16/2002	6.35
		12/5/2002	6.52
		12/17/2002	6.58
		3/12/2003	5.61
		3/21/2003	7.46
		6/23/2003	7.44
	MW-9S	9/28/2000	5.83
		10/5/2000	5.87
		2/21/2001	4.79
		7/23/2001	5.15
		7/27/2001	4.29
		10/30/2001	4.37
		12/19/2001	3.91
		3/5/2002	4.75
		5/30/2002	4.06
		8/16/2002	4.79
		12/17/2002	7.06
		3/21/2003	4.49
		6/23/2003	3.96
3	MW-A13	12/17/2002	5.1
		3/21/2003	4.96
		6/23/2003	4.35
	MW-A22	12/17/2002	5.43
		3/21/2003	4.04
		6/23/2003	3.96
6C	B25MW1	10/5/2000	9.62
		1/10/2001	9.92
		5/9/2001	9.02
		7/23/2001	9.70
		10/24/2001	9.08
		3/11/2002	9.42
		3/21/2002	9.34
		5/31/2002	10.93
	MW5	7/28/2000	9.34
		10/5/2000	9.10
		1/5/2001	9.51
		1/11/2001	9.45
		5/7/2001	9.53
		7/24/2001	9.35
		7/28/2001	9.35
	MW5DS	1/5/2001	8.18
		1/8/2001	8.06
		5/7/2001	8.48
		7/19/2001	7.94
		10/25/2001	7.39
		3/11/2002	7.91
		5/31/2002	8.16
		8/16/2002	8.26
		12/11/2002	8.27
		12/16/2002	8.38
		3/21/2003	8.74
		6/24/2003	7.64

Figures



Legend

- 1 - Runway Protection Zone
- 2 - Demolished Area
- 3 - Retained Area
- 4 - Power Plant
- 5 - Industrial Water Treatment Plant
- 6A, 6B, 6C - GKN Facility
- 7 - Engineering Campus
- 8 - Office Complex North
- 9 - Gun Range
- Buildings
- Roads
- Railroads

Drawn by: BSM Approved by: SRC

Checked by: Date: March 7, 2005

MACTEC, Inc.

Figure 1-1
Risk Assessment Exposure Area Map,
Boeing Tract 1
Hazelwood, Missouri

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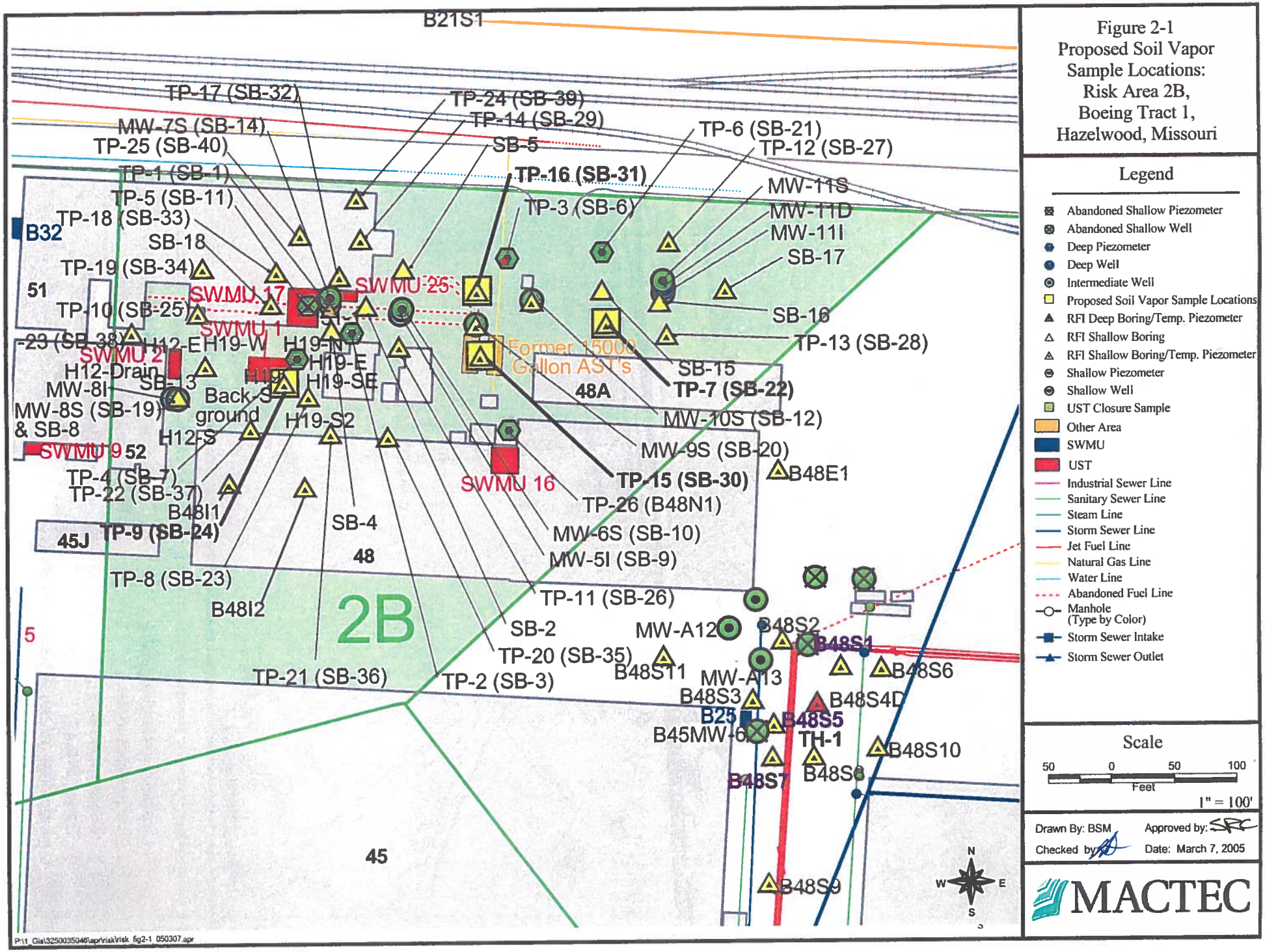

Figure 2-1
Proposed Soil Vapor Sample Locations:
Risk Area 2B,
Boeing Tract 1,
Hazelwood, Missouri

Legend

- Abandoned Shallow Piezometer
- Abandoned Shallow Well
- Deep Piezometer
- Deep Well
- Intermediate Well
- Proposed Soil Vapor Sample Locations
- RFI Deep Boring/Temp. Piezometer
- RFI Shallow Boring
- RFI Shallow Boring/Temp. Piezometer
- Shallow Piezometer
- Shallow Well
- UST Closure Sample
- Other Area
- SWMU
- UST
- Industrial Sewer Line
- Sanitary Sewer Line
- Steam Line
- Storm Sewer Line
- Jet Fuel Line
- Natural Gas Line
- Water Line
- Abandoned Fuel Line
- Manhole (Type by Color)
- Storm Sewer Intake
- Storm Sewer Outlet

Scale

50 0 50 100
Feet
1" = 100'

Drawn By: BSM
Approved by: SRC
Checked by: AD
Date: March 7, 2005

MACTEC

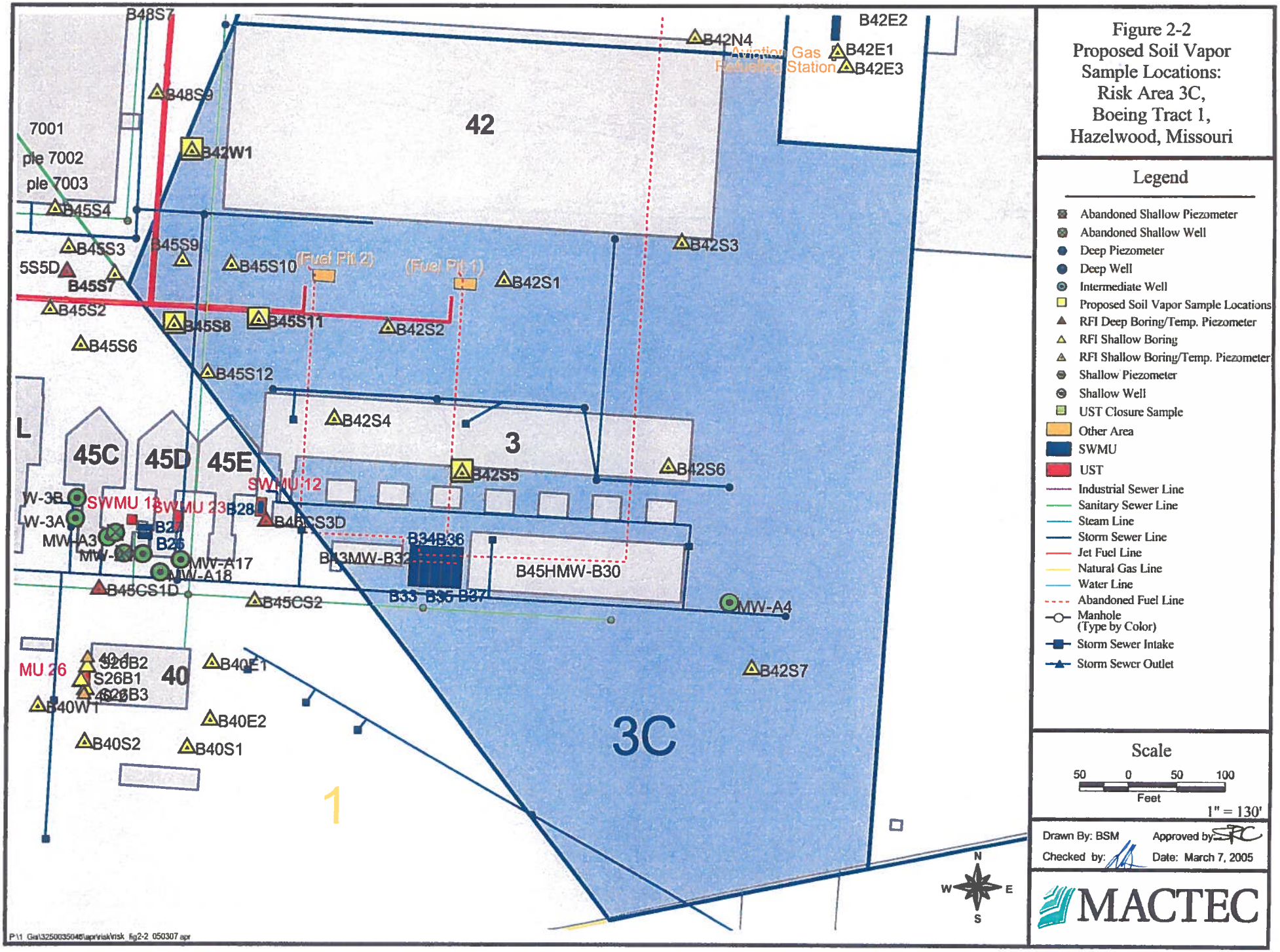

Figure 2-2
Proposed Soil Vapor Sample Locations:
Risk Area 3C,
Boeing Tract 1,
Hazelwood, Missouri

Legend

- Abandoned Shallow Piezometer
- Abandoned Shallow Well
- Deep Piezometer
- Deep Well
- Intermediate Well
- Proposed Soil Vapor Sample Locations
- RFI Deep Boring/Temp. Piezometer
- RFI Shallow Boring
- RFI Shallow Boring/Temp. Piezometer
- Shallow Piezometer
- Shallow Well
- UST Closure Sample
- Other Area
- SWMU
- UST
- Industrial Sewer Line
- Sanitary Sewer Line
- Steam Line
- Storm Sewer Line
- Jet Fuel Line
- Natural Gas Line
- Water Line
- Abandoned Fuel Line
- Manhole (Type by Color)
- Storm Sewer Intake
- Storm Sewer Outlet

Scale

50 0 50 100
Feet
1" = 130'

Drawn By: BSM
Approved by:
Checked by:
Date: March 7, 2005

MACTEC

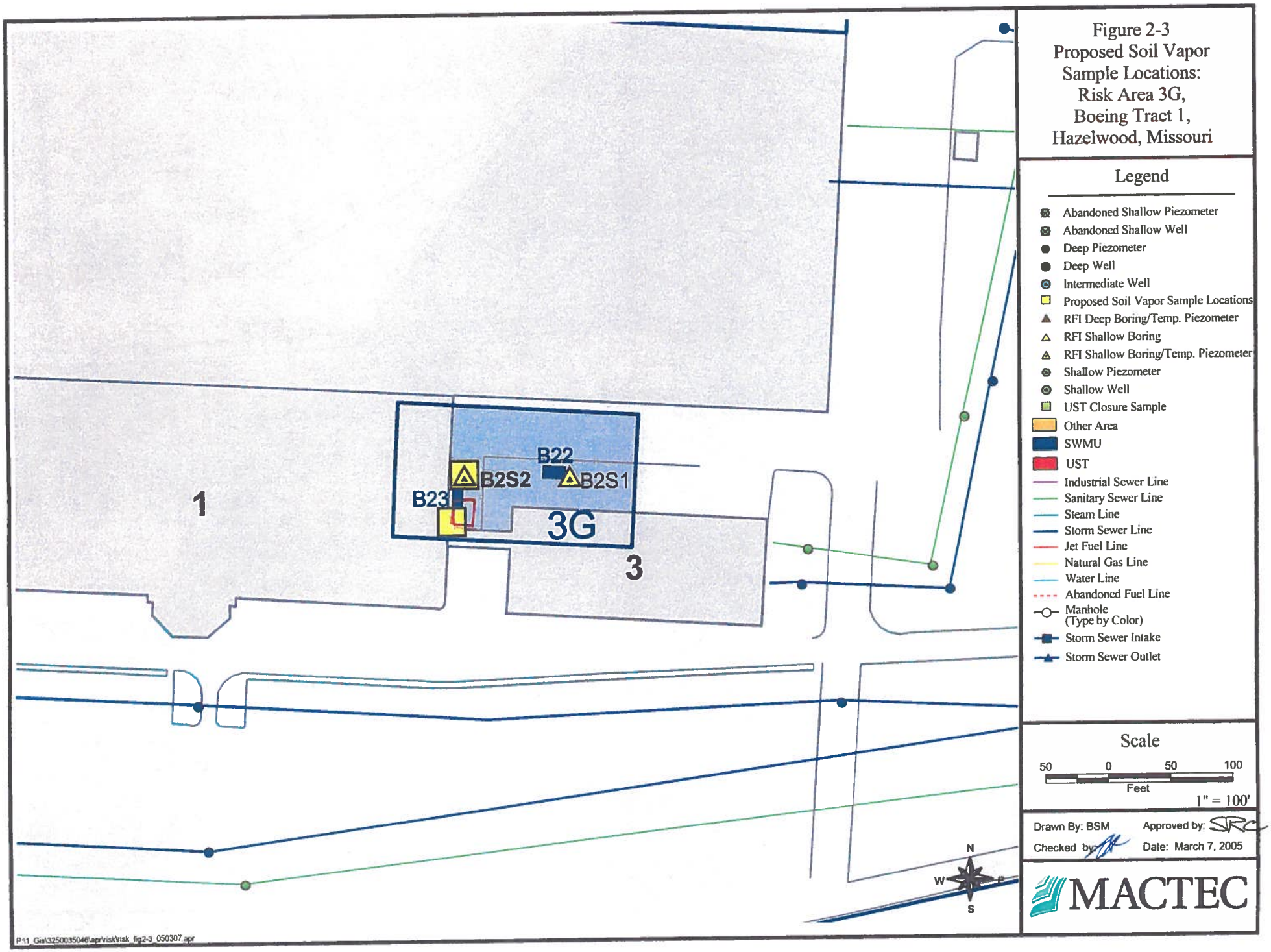

Figure 2-3
Proposed Soil Vapor Sample Locations: Risk Area 3G, Boeing Tract 1, Hazelwood, Missouri

Legend

- Abandoned Shallow Piezometer
- Abandoned Shallow Well
- Deep Piezometer
- Deep Well
- Intermediate Well
- Proposed Soil Vapor Sample Locations
- RFI Deep Boring/Temp. Piezometer
- RFI Shallow Boring
- RFI Shallow Boring/Temp. Piezometer
- Shallow Piezometer
- Shallow Well
- UST Closure Sample
- Other Area
- SWMU
- UST
- Industrial Sewer Line
- Sanitary Sewer Line
- Steam Line
- Storm Sewer Line
- Jet Fuel Line
- Natural Gas Line
- Water Line
- Abandoned Fuel Line
- Manhole (Type by Color)
- Storm Sewer Intake
- Storm Sewer Outlet

Scale

50 0 50 100

Feet

1" = 100'

Drawn By: BSM Approved by: SRC

Checked by: Date: March 7, 2005

MACTEC

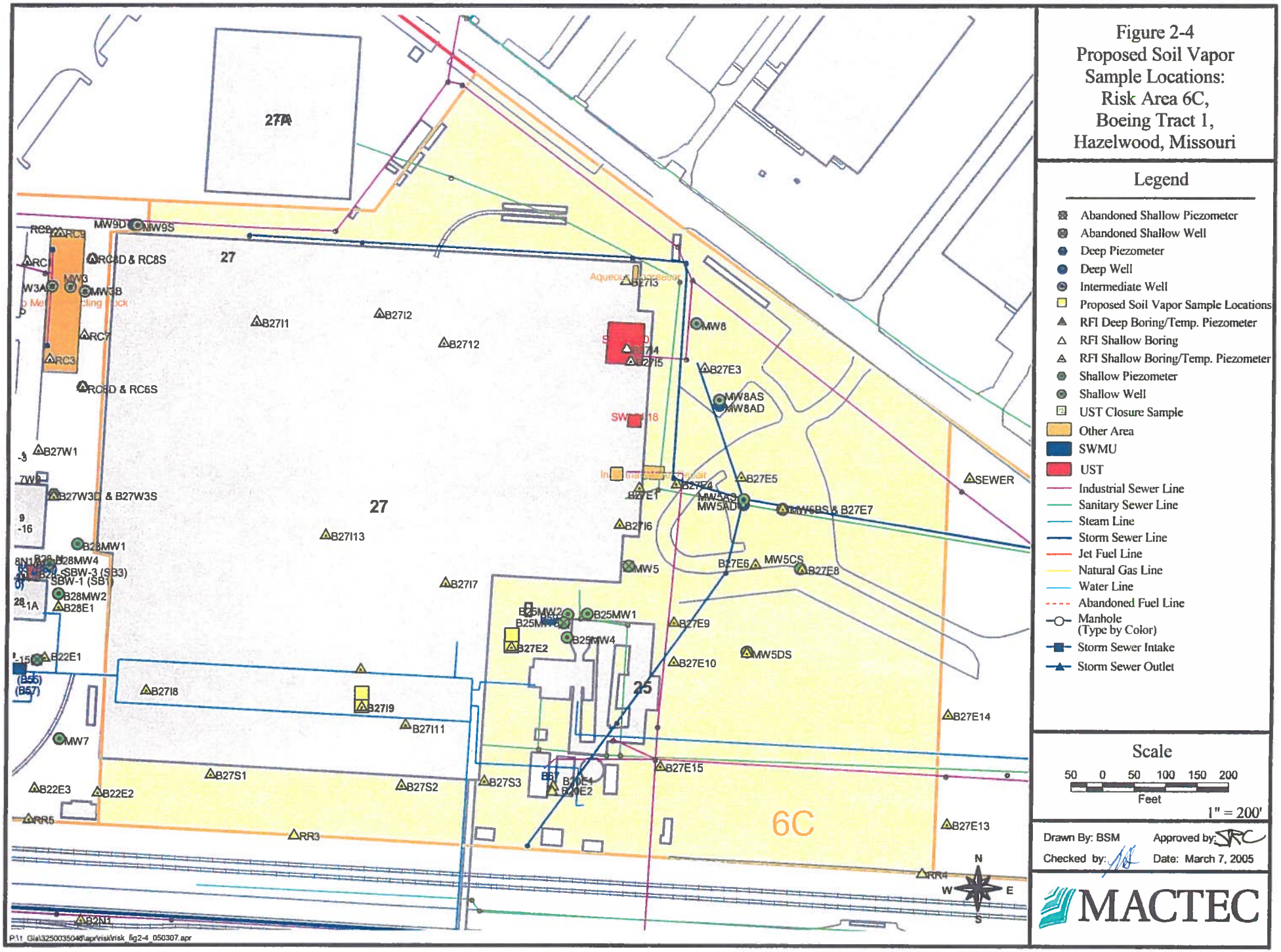

Figure 2-4
Proposed Soil Vapor Sample Locations: Risk Area 6C, Boeing Tract 1, Hazelwood, Missouri

Legend

- Abandoned Shallow Piezometer
- Abandoned Shallow Well
- Deep Piezometer
- Deep Well
- Intermediate Well
- Proposed Soil Vapor Sample Locations
- RFI Deep Boring/Temp. Piezometer
- RFI Shallow Boring
- RFI Shallow Boring/Temp. Piezometer
- Shallow Piezometer
- Shallow Well
- UST Closure Sample
- Other Area
- SWMU
- UST
- Industrial Sewer Line
- Sanitary Sewer Line
- Steam Line
- Storm Sewer Line
- Jet Fuel Line
- Natural Gas Line
- Water Line
- Abandoned Fuel Line
- Manhole (Type by Color)
- Storm Sewer Intake
- Storm Sewer Outlet

Scale

50 0 50 100 150 200

Feet

1" = 200'

Drawn By: BSM Approved by:

Checked by: Date: March 7, 2005

MACTEC

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Appendix A

Guide to Air Sampling and Analysis, Canisters and Tedlar® Bags, Fourth Edition, Air Toxics Ltd

Guide To Air Sampling and Analysis

Canisters and Tedlar Bags

Fourth Edition

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AIR TOXICS LTD.

AN ENVIRONMENTAL ANALYTICAL LABORATORY

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Tables

Section 1.0 Introduction

Air Toxics Ltd. presents this guide as a resource for individuals engaged in air sampling. Air sampling can be more involved than water or soil sampling due to the reactivity of chemical compounds in the gas matrix and sample interaction with the sampling equipment and media. Ensuring that air samples are collected properly is an important step in acquiring meaningful analytical results. This guide is not a substitute for experience and cannot possibly address the multitude of actual field conditions. Note that this guide is intended for typical projects involving whole air sampling of volatile organic compounds (VOCs) in canisters and Tedlar bags. Air Toxics Ltd. provides the "Guide to Air Sampling and Analysis - Sorbents, Solutions, and Filters" for other types of sampling.

1.1 Whole Air Sampling of VOCs

There are four general ways to collect compounds in a gas phase sample. A sampler can collect the gas in a container or draw the gas through a sorbent, solution, or filter. This guide focuses on collecting a sample in the most common air sampling containers, Summa canisters and Tedlar bags. The sample can be collected in the container either passively (i.e., by evacuating the canister prior to sampling) or actively (i.e., using a pump). The container is subsequently sealed and transported to the laboratory for analysis. The sample is referred to as a "whole air sample" and the compounds remain in the gas matrix (e.g., ambient air) inside the container.

As a general rule, whole air sampling is best when target compounds are volatile, non-polar, and have boiling points less than 170°C, although exceptions to this rule can be found. Recovery of any given compound in a whole air sample is very much dependent upon the humidity of the sample, the chemical activity of the sample matrix, and the degree of inertness of the container.

1.2 Choosing Between Canisters and Tedlar Bags

Deciding whether a canister or a Tedlar bag should be used for collecting a whole air sample depends on the type of air sampling application. The Tedlar bag is best used as a "ppmv" (parts per million by volume) whole air sample container. In other words, it is best suited for air sampling applications involving compound concentrations well above the low ppbv (parts per billion by volume) range. Soil/landfill gas surveys, monitoring soil vapor extraction (SVE) systems, and sampling for atmospheric/fixed gases are applications well suited for Tedlar bag sampling. Ambient and indoor air projects driven by risk assessment or litigation are better suited for Summa canisters that are cleaned and individually certified free of the target compounds. The different degree of compound inertness between the two sample container surfaces is reflected in their suggested hold times for VOCs – 3 days from sampling to analysis for a Tedlar bag compared to 14-30 days for a Summa canister. Analyses of new Tedlar bags reveal that some VOCs may be present at concentrations in the single digit ppbv range (see Section 3).

Table 1.2. Comparison of Canisters to Tedlar Bags

	Canisters	Tedlar Bags
Common Volumes	1 and 6 L	1, 3, and 5 L
Type of Sampling	Passive (vacuum)	Active (pump required)
Sample Handling	Room temperature	Room temperature
Media Hold Time	Up to 30 days recommended	Indefinite
Hold Time to Analysis	14-30 days	3 days
Surface Inertness	Excellent	Fair
Cleanliness	10% or 100% certified to ppbv/pptv levels	Some VOCs present at 0.5 to 45 ppbv
Sampling Application	Ambient/indoor air, soil/landfill gas, stationary source	Ambient air (fixed gases only), soil/landfill gas, stationary source
Rule of Thumb	"ppbv device"	"ppmv device"
Advantages	Inertness, hold time, ruggedness, no pump	Purchase/shipping cost, availability, convenience

The table above compares the features of canisters and Tedlar bags. Canisters have superior inertness, hold time to analysis, ruggedness, and do not require a sampling pump. Tedlar bags can be purchased inexpensively in bulk, carried to a sampling site in a briefcase, filled in seconds, and shipped easily to the laboratory for analysis. Call Client Services at 800-985-5955 if you have questions regarding sampling media.

1.3 Organization of this Guide

The remainder of this guide is divided into three sections: canister sampling, Tedlar bag sampling, and special sampling considerations. Section 2 on canister sampling and Section 3 on Tedlar bag sampling provide complete sampling media descriptions, practical considerations for sampling, and step-by-step sampling procedures. Photographs illustrate the correct way to assemble the various sampling components. Tables provide detailed information on many operational factors that ultimately influence the quality of the data obtained from a canister or Tedlar bag sample. Section 4 provides considerations for special sampling configurations such as field duplicates and ambient blanks. This section also provides considerations for sampling at altitude, soil/landfill gas sampling, and sample cylinder (or "sample bomb") sampling.

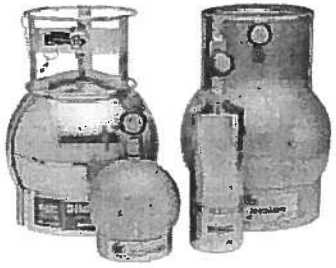
If you have any questions after reading this guide, please call Client Services at 800-985-5955 before proceeding with sampling. Air Toxics Ltd. also provides technical articles on specific air topics in *Air Topics* publications and *In the Air* quarterly newsletters available upon request or on the Internet at *www.airtoxics.com*.

Section 2. Canister Sampling

This section provides a description of air sampling canisters, practical considerations for sampling, and step-by-step instructions for collecting a grab and integrated sample. Photographs illustrate the correct way to assemble the various sampling components. Tables provide detailed information on many operational factors that ultimately influence the quality of the data obtained from a canister sample.

2.1 Introduction to Canisters

An air sampling canister is a container for collecting a whole air sample for ambient and indoor air applications. The canister is best suited for projects involving analysis of compounds in the ppbv range. However, canisters can be used for other applications such as landfill and soil gas involving analysis of compounds in the ppmv range.



A canister can be spherical or cylindrical and is constructed of stainless steel. The canister is prepared for sampling by evacuating the contents to a vacuum of approximately 29.9 inches of Mercury (in. Hg). Opening the stainless steel bellows valve allows the air sample to enter the canister. When the target volume of sample is collected, the valve is closed and the canister is returned to the laboratory.

Canisters can range in volume from less than 1 liter (L) to greater than 6 L. At Air Toxics Ltd., 6 L canisters are used for ambient air samples and for taking integrated samples. 1 L canisters are normally used for taking high concentration (i.e., greater than 5 ppbv) grab samples, although exceptions to these guidelines are common. Variations of air sampling canisters include glass bulbs, sample cylinders (or "sample bombs"), and Summa canisters. Glass bulbs are rarely used in field applications due to lack of ruggedness. Sample cylinders are DOT-approved, high pressure, thick-walled, stainless steel cylinders with a valve at each end (see Section 4.4). The remainder of this section focuses on Summa canisters.

2.1.1 Summa Canister

A Summa canister is a stainless steel container that has had the internal surfaces specially passivated using a "Summa" process. This process combines an electropolishing step with a chemical deactivation step to produce a surface that is nearly chemically inert. A Summa surface has the appearance of a mirror: bright, shiny, and smooth. The degree of chemical inertness of a whole air sample container is crucial to minimizing reactions with the sample and maximizing recovery of target compounds from the container. Air Toxics Ltd. maintains a large inventory of Summa canisters in 6 and 1 L volumes.

2.1.2 Canister Cleaning and Hold Time

Canister sampling differs considerably from collecting a water sample in a VOA vial or a soil sample in an amber jar in that the container (valued at over $450) is cleaned and reused. A canister will hold a high vacuum (i.e., greater than 25 in. Hg) for more than 30 days. Air Toxics Ltd., however, requires that our canisters be returned within 30 days.

☞ Media hold time for a canister is 30 days

Air Toxics Ltd. provides two types of canister cleaning certification, 10% and 100%, depending upon the requirements of the project. The 10% certification process is appropriate for routine ambient air applications and high concentration applications such as soil vapor and landfill gas monitoring. The 10% certification process begins by cleaning canisters using a combination of dilution, heat, and high vacuum. After completing the cleaning steps, 10% of the canisters are certified each day. Canisters are certified for approximately 60 VOCs using GC/MS by Modified EPA Method TO-15. The 10% certification process requires that target compound concentrations be below 0.2 ppbv. Alternatively, the 100% certification (i.e., individual certification) process is appropriate for ambient and indoor air applications driven by risk assessment or litigation that require pptv (parts per trillion by volume) sensitivity. Similar to the 10% certification, the 100% certification also begins with the canister cleaning process. The difference with the 100% certification is that canisters are individually certified for a client-specific list of target compounds using GC/MS by TO-15. The 100% certified canisters are shipped with analytical documentation demonstrating that they are free of the target compounds down to the project reporting limits.

☞ Specify whether your project requires 10% or 100% canister cleaning certification

Although 14 days is the most commonly cited hold time for a canister sample, the hold time is compound specific. For example, non-polar compounds such as chloroform, benzene, and vinyl chloride are stable in a canister for at least 30 days. In fact, EPA Method TO-15 states: "Fortunately, under conditions of normal usage for sampling ambient air, most VOCs can be recovered from canisters near their original concentrations for after storage times of up to thirty days". However, recovery of polar compounds such as methanol and acetone begin to drop significantly after 14 days. Analysis of these samples should be performed within 14 days.

☞ Sample hold time to analysis for a canister is 14-30 days for VOCs

2.2 Associated Canister Hardware

Associated hardware used with the canister includes the valve, brass cap, particulate filter, and vacuum gauge.

2.2.1 Valve

An industry standard, 1/4 in. stainless steel bellows valve (manufactured by Nupro) is mounted at the top of the canister. The valve allows vacuum to be maintained in the canister prior to sampling and seals off the canister once the sample has been collected. No more than a half turn by hand is required to open the valve. Do not over-tighten the valve after sampling or it may become damaged. A damaged valve can leak and possibly compromise the sample. Some canisters have a metal cage near the top to protect the valve.

2.2.2 Brass Cap

Each canister comes with a brass cap (i.e., Swagelok 1/4 in. plug) secured to the inlet of the valve assembly. The cap serves two purposes. First, it ensures that there is no loss of vacuum due to a leaky valve or valve that is accidentally opened during handling. Second, it prevents dust and other particulate matter from fouling the valve. The cap is removed prior to sampling and replaced following sample collection.

☞ Always replace the brass cap following canister sampling

7 Micron

5 Micron

2.2.3 Particulate Filter

Each canister comes with a particulate filter provided separately in the packing box. The filter prevents particulate matter from fouling the valve (or flow controller) and entering the canister. Particulate filters should be cleaned between uses. Air Toxics Ltd. provides two types of particulate filters: 7 micron and 5 micron. The longer, 7 micron particulate filter is normally used with 6 L canisters and whenever an integrated sample is being collected. This device filters particulate matter greater than 7 microns in diameter and does not significantly restrict the flow rate in to the canister. Typical fill times for canisters are shown in the following table. The shorter, 5 micron particulate filter is often used to slow down grab sampling with 1 L canisters and mini-cans. This device is a fritted stainless steel disk that has been pressed into a conventional Swagelok adapter. This device filters particulate matter greater than 5 microns in diameter and has a relatively high pressure drop across the fritted disk. It restricts the flow into the canister and fill times are increased.

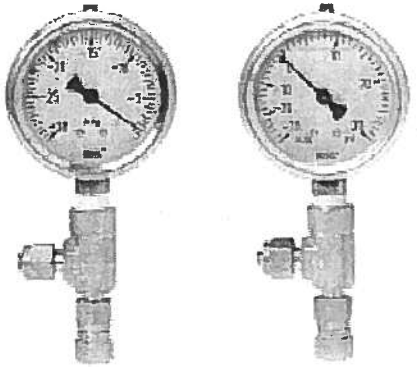
☞ Always use the particulate filter for canister sampling

Table 2.2.3 Fill Times for Canisters

CANISTER VOLUME	7 micron filter	5 micron filter
6 L	16 sec	23 min
1 L	3 sec	4 min
400 mL (mini-can)	1-2 sec	1 min 20 sec

2.2.4 Vacuum Gauge

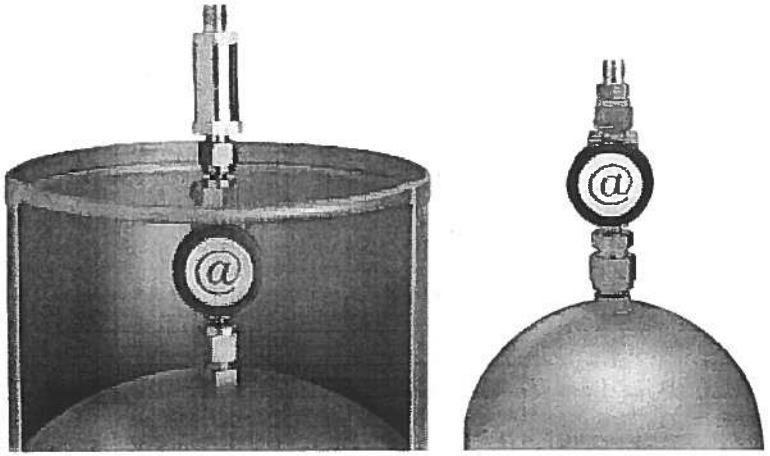
A vacuum gauge can be used to measure the initial vacuum of the canister before sampling and the final vacuum upon completion. A gauge can also be used to monitor the fill rate of the canister when collecting an integrated sample. Gauges are generally not used during the brief interval for grab sampling. Gauges are used only to provide a relative measure of "change". The accuracy of gauges provided by Air Toxics Ltd. is such that gauge-to-gauge comparisons have no merit. Individuals engaged in frequent air sampling or air projects driven by risk assessment or litigation are highly encouraged to purchase and maintain their own gauge. Upon request, Air Toxics Ltd. provides two types of gauges: vacuum gauges reading 0 to 30 in. Hg and vacuum-pressure gauges reading 30 in. Hg to 30 psig (pounds per square inch gage).



☞ Air Toxics Ltd. provides gauges only if requested

2.3 Grab Sampling with Canisters

There are two basic modes of canister sampling: grab and integrated. A grab sample is taken over a short interval (i.e., 1-5 minutes) while an integrated sample is taken over an extended period (e.g., 0.5-2 hours for a 1 L canister and 0.5-24 hours for a 6 L canister). In both modes the canister vacuum is used to draw sample into the canister. This is commonly referred to as passive sampling. Active sampling utilizes a pump to fill the canister. The most common hardware configuration used to take a grab sample are illustrated in the following figure. A particulate filter is used to prevent particulate matter from fouling the valve and entering the canister.



2.3.1 Considerations for Grab Sampling With Canisters

The following are some considerations for collecting a grab sample in a canister.

- **Avoid Leaks in Sampling Train**: All fittings on the sampling hardware are 1/4 in. Swagelok. A 9/16 in. crescent wrench is used to assemble the hardware. It is not necessary to over tighten the fittings; finger tight plus 1/4 turn with the wrench is adequate. In practice this should be tight enough so that the various pieces of equipment, when assembled, cannot be rotated by hand.

- **Verify Gauge Operation**: If the indicator does not read "zero" upon arrival, the gauge either needs to equilibrated or the gauge may be damaged and unusable. Equilibrate the gauge by "cracking" the rubber plug on top of the gauge. For more details on the equilibration procedure, see instructions included with the gauge or call Client Services at 800-985-5955.

- **Verify Initial Vacuum of Canister**: Prior to shipment, each canister is checked for mechanical integrity. However, it is still important to check the vacuum of the canister prior to use and record the initial vacuum on the chain-of-custody. The initial vacuum of the canister should be greater than 25 in. Hg. If the canister vacuum is less than 25 in. Hg, do not use it. Call Client Services at 800-985-5955 and arrange for a replacement canister. If sampling at altitude, there are special considerations for gauge readings and sampling (see Section 4.2). The procedure to verify the initial vacuum of a canister is simple, but unforgiving.

1. Confirm that valve is closed (knob should already be tightened clockwise)
2. Remove the brass cap
3. Attach gauge
4. Attach brass cap to side of gauge tee fitting
5. Open and close valve quickly (a few seconds)
6. Read vacuum on the gauge
7. Record gauge reading on "Initial Vacuum" column of chain-of-custody
8. Verify that canister valve is closed and remove gauge
9. Replace the brass cap

- **Leave Residual Vacuum**: A grab sample can be collected either by allowing the canister to reach ambient conditions or by leaving some residual vacuum (e.g., 5 in. Hg) in the canister. In either case, the final vacuum should be noted on the "Final Vacuum" column on the chain-of-custody. This will enable the laboratory to compare the final vacuum with the receipt vacuum (i.e., the vacuum measured upon arrival at the laboratory). If the two readings differ significantly, Client Services will contact you for instructions on how to proceed.

2.3.2 Step-by-Step Procedures for Canister Grab Sampling

These procedures are for a typical ambient air sampling application and actual field conditions and procedures may vary.

Before you get to the field:

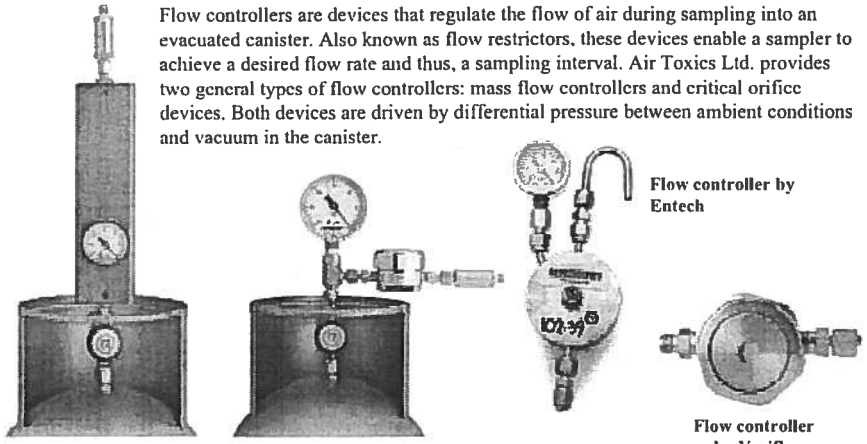
1. Verify contents of the shipped package (e.g., chain-of-custody, canister, particulate filter, and gauge – if requested)
2. Verify that gauge is working properly (see Section 2.3.1)
3. Verify and record initial vacuum of canister (see Section 2.3.1)

When ready to sample:

4. Remove brass cap
5. Attach particulate filter to canister
6. Open valve 1/2 turn (6 L canister normally takes about 16 sec to fill)
7. Close valve by hand tightening knob clockwise
8. Verify and record final vacuum of canister (repeat steps used to verify initial vacuum)
9. Replace brass cap
10. Fill out canister sample tag
11. Return canister in box provided
    - Unreturned canister charge of $450 each
12. Return sample media in packaging provided. Unreturned equipment charges:
    - $45 per particulate filter
    - $45 per gauge
13. Fill out chain-of-custody and relinquish samples properly
14. Place chain-of-custody in box and retain pink copy
15. Tape box shut and affix custody seal (if applicable) across flap
16. Ship accordingly to meet method holding times

2.4 Integrated Sampling with Canisters and Flow Controllers

An air sample collected over more than a few minutes is referred to as an integrated sample and can provide information on compound concentrations in air averaged or composited over time. An 8- or 10-hour integrated sample can be used to determine indoor air quality in the workplace. Similarly, a 24-hour integrated sample can be an economical and practical approach to determine residential exposure to indoor or outdoor air sources. The most common hardware configurations used to take an integrated sample are illustrated below.



Flow controller by Entech

Flow controller by Veriflo

Flow controllers are devices that regulate the flow of air during sampling into an evacuated canister. Also known as flow restrictors, these devices enable a sampler to achieve a desired flow rate and thus, a sampling interval. Air Toxics Ltd. provides two general types of flow controllers: mass flow controllers and critical orifice devices. Both devices are driven by differential pressure between ambient conditions and vacuum in the canister.

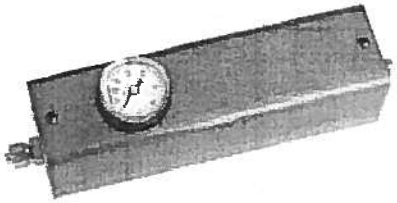
2.4.1 Mass Flow Controller

A mass flow controller employs a diaphragm that actively compensates to maintain a constant mass flow rate. As the differential pressure decreases, the flow rate tends to decrease and the diaphragm responds by opening up to allow more air to pass through. Mass flow controllers can be adjustable or fixed and can provide integrated samples with intervals ranging from hours to days. Air Toxics Ltd. provides a fixed mass flow controller that is calibrated at the laboratory for 24-hour sampling. Adjustable mass flow controllers have a knob that can be adjusted in the field to provide integrated samples with intervals ranging from one to 24 hours. The rugged conditions of field sampling are not usually compatible with adjustable mass flow controllers and Air Toxics Ltd. designed a more reliable flow controller based on a critical orifice design.

2.4.2 Critical Orifice Device

Air Toxics Ltd. designed a critical orifice flow restrictor to provide integrated samples with intervals from 0.5 to 8 hours. The device restricts air flow by forcing the sample to enter a capillary column of minute radius. This device is passive compared to an actively compensating diaphragm and the flow rate decreases as the driving force (differential pressure) decreases. For sampling intervals from 0.5 to

8 hours, however, the flow rate is relatively constant. The main advantages of the Air Toxics Ltd. flow restrictors are improved ruggedness and cleanliness. With no moving or adjustable parts, the Air Toxics Ltd. design is unlikely to lose its flow setting. In addition, a vacuum gauge is built in to the device to monitor sampling progress. To ensure there are no contamination issues from previous use, the capillary column is replaced before shipping to the field.



2.4.3 Sampling Interval and Flow Controller Setting

When you request canisters and flow controllers from Air Toxics Ltd., you will be asked for the sampling interval, and the flow controllers will be pre-set prior to shipment according to the table below. The flow controller is set to collect 5 L of sample over the sample interval. Final canister vacuum is targeted at 5 in. Hg. The flow rate is set at standard atmospheric conditions (approximately sea level). If the air sample is a process (pressurized or under vacuum) or is collected at elevation, the canisters will fill faster or slower depending on the sampling conditions. If you specify the pressure of the source at project set-up, we can set the flow controller accordingly. See Section 4 for a discussion of collecting a sample at elevation. The 24-hr flow controllers should not be used for process or source samples.

Table 2.4.3 Flow Rates for Selected Sampling Intervals (mL/min)

Sampling Interval (hrs)	0.5	1	2	4	8	12	24
6 L Canister	167	83.3	41.7	20.8	11.5	7.6	3.5
1 L Canister	26.6	13.3	6.7	-	-	-	-

Note: Target fill volumes for 6 L and 1 L canisters are 5,000 mL and 800 mL, respectively.

$$\text{Flow Rate(mL/min)} = \frac{\text{Target Fill Volume (mL)}}{\text{Sampling Interval (min)}}$$

2.4.4 Final Canister Vacuum and Flow Controller Performance

Ideally the final vacuum of a 6 L canister should be 5 in. Hg or greater. As long as the differential pressure is greater than 4 in. Hg ambient pressure, then the flow through the device will remain approximately constant as the canister fills. If there is insufficient differential pressure, the flow through the controller will decrease as the canister pressure approaches ambient. Because of the normal fluctuations in the flow rate (due to changes in ambient temperature, pressure, and diaphragm instabilities) during sampling, the final vacuum will range between 2 and 10 in. Hg.

- **If the residual canister vacuum is greater than 5 in. Hg** (i.e., more vacuum), the flow rate was low and less than 5 L of sample was collected. When the canister is pressurized to 5 psig prior to analysis, sample dilution will be greater than normal. This will result in elevated reporting limits.
- **If the residual canister vacuum is less than 5 in. Hg** (i.e., less vacuum), the initial flow rate was high. Once the vacuum decreases below 5 in. Hg, the flow rate begins to drop significantly. This scenario indicates that the sample is skewed in favor of the first portion of the sampling interval.
- **If the final vacuum is near ambient** (i.e., less than 1 in. Hg), there is inadequate differential pressure to drive the flow controller. The sampler cannot be certain the desired sampling interval was achieved before the canister arrived at ambient conditions. The sample could have been acquired over a 1-hour interval (which would be the case if the connection between the canister and flow controller leaked or if the flow controller malfunctioned) or a 24-hour interval. Although the actual sampling interval is uncertain, the canister still contains sample from the site.

Table 2.4.4 Relationship Between Final Canister Vacuum, Volume Sampled, and Dilution Factor (6 L Canister)

Final Vacuum (In. Hg)	0	2.5	5	7.5	10	12.5	15	17.5	20
Volume Sampled (L)	6	5.5	5	4.5	4	3.5	3	2.5	2
Dilution Factor*	1.34	1.46	1.61	1.79	2.01	2.30	2.68	3.22	4.02

* Canister pressurized to 5 psig for analysis

$$\text{Final Reporting Limit} = \text{Method Reporting Limit} \times \text{Dilution Factor (Canister Pressurization)} \times \text{Dilution Factor (Sample Concentration)}$$

$$\text{Dilution Factor (Canister Pressurization)} = \frac{\text{Pressurization for Analysis}}{\text{Receipt Vacuum}} = \frac{14.7 \text{ psig} + \text{Press. for Analysis (psig)}}{14.7 \text{ psig} \left[1 - \frac{\text{Rec. Vac. (in. Hg)}}{29.9 \text{ in. Hg}}\right]}$$

2.4.5 Considerations for Integrated Sampling with Canisters

Collecting an integrated air sample is more involved than collecting a grab sample. Sampling considerations include verifying that the media is ready, monitoring the integrated sampling progress, and avoiding contamination.

- **Avoid Leaks in the Sampling Train**: See Section 2.3.1 for instructions on how to securely assemble sampling hardware. A leak in any one of these connections means that some air will be pulled in through the leak and not through the flow controller. A final pressure near ambient is one indication that there may have been a leak.

- **Verify Initial Vacuum of Canister:** See Section 2.3.1 for instructions on verifying initial canister vacuum. If you are using an Air Toxics Ltd. critical orifice flow controller, note that you can use the built-in gauge. It is important to note both the canister and flow controller serial numbers on the chain-of-custody.
- **Monitor Integrated Sampling Progress:** It is a good idea to monitor the progress of the integrated sampling during the sampling interval. The volume of air sampled is a linear function of canister vacuum. For example, halfway (4 hours) into an 8-hour sampling interval, the canister should be half filled (2.5 L) and the gauge should read approximately 17 in. Hg. More vacuum than 17 in. Hg indicates that the canister is filling too slowly; less than 17 in. Hg and the canister is filling too quickly. If the canister is filling too slowly, a valid sample can still be collected (see Section 2.4.4). If the canister is filling too quickly because of a leak or incorrect flow controller setting, corrective action can be taken. Ensuring all connections are tight may eliminate a leak. It is possible to take an intermittent sample. The time interval need not be continuous. Eight 1-hour increments, taken by opening and closing the canister valve, will yield a valid sample.

Table 2.4.5 Gauge Readings for an 8-Hour Sampling Interval

Sampling Interval (hrs)	0	4	8
Canister Vacuum (in. Hg)	29.9	17.4	5
Volume Sampled (L)	0	2.5	5

- **Avoid Contamination**: Flow controllers should be cleaned between uses. This is normally accomplished by returning them to the laboratory. For large air sampling projects, Air Toxics Ltd. has designed a field conditioning program for 24-hour flow controllers involving a purge manifold. This arrangement provides the sampler with scheduling flexibility, inventory control, and convenience in the field. Air Toxics Ltd. will provide the 24-hour flow controllers, a purge manifold, Teflon tubing, rubber ferrules, vacuum pump, and flow meter. The sampler will need to provide the certified nitrogen cylinder and the certified high pressure regulator. Call Client Services at 800-985-5955 if you are interested in the field conditioning program.
- **Keep Sampling Train Out of Direct Sunlight:** The sampling train should be kept out of direct sunlight during sampling. There will be some flow rate drift if the temperature of the controllers is allowed to vary significantly.

2.4.6 Step-by-Step Procedures for Integrated Sampling

These procedures are for a typical ambient air sampling application and actual field conditions and procedures may vary.

Before you get to the field:

1. Verify contents of the shipped package (e.g., chain-of-custody, canister, particulate filter, and flow controller)
2. Verify initial vacuum of canister (see Section 2.3.1)

When ready to sample:

3. Remove brass cap
4. Attach flow controller to canister
5. Attach particulate filter to flow controller
6. Open valve 1/2 turn
7. Monitor integrated sampling progress periodically (see Section 2.4.5)

At end of sampling interval:

8. Verify and record final vacuum of canister (for 24-hr flow controller repeat steps used to verify initial vacuum and for critical orifice device simply read built-in gauge)
9. Close valve by hand tightening knob clockwise
10. Replace brass cap
11. Fill out canister sample tag
12. Return canisters in boxes provided
    - Unreturned canister charge of $450 each
13. Return sample media in packaging provided. Unreturned equipment charges:
    - $45 per particulate filter
    - $50-500 per flow controller
14. Fill out chain-of-custody and relinquish samples properly
15. Place chain-of-custody in box and retain pink copy
16. Tape box shut and affix custody seal (if applicable) across flap
17. Ship accordingly to meet method holding times

Section 3. Tedlar Bag Sampling

This section provides a description of Tedlar bags, practical considerations for sampling, and step-by-step instructions for collecting a grab sample. Photographs illustrate the correct way to assemble the various sampling components.

3.1 Introduction to Tedlar Bags

A Tedlar bag is a container used to collect a whole air sample for landfill gas, soil gas, and stationary source applications. The Tedlar bag is best suited for projects involving analysis of compounds in the ppmv range. However, Tedlar bags can be used for other applications such as ambient air monitoring for atmospheric/fixed gases. They can be used to collect sulfur compounds, but only if the fittings are non-metallic (e.g., polypropylene, Teflon, or Nylon).

A Tedlar bag is made of two plies of Tedlar film sealed together at the edges and features a valve that allows the interior to be filled. Sample collection requires a pressurized sampling port, a low flow rate pump, or a lung sampler. The bag expands as sample enters. When the target volume of sample is collected, the valve is closed and the Tedlar bag is returned to the laboratory. Air Toxics Ltd. maintains a limited inventory of Tedlar bags in 1 L , 3 L, and 5 L volumes.

3.1.1 Tedlar Film

Tedlar is a trade name for polyvinyl fluoride film developed by DuPont Corporation in the 1960's. This patented fluoropolymer has been used in a wide variety of applications including protective surfacing for signs, exterior wall panels, and aircraft interiors. Tedlar film is tough, yet flexible and retains its impressive mechanical properties over a wide range of temperatures (well below freezing to over 200° F). Tedlar exhibits low permeability to gases, good chemical inertness, good weathering resistance, and low off-gassing.

3.1.2 How "Active" is the Surface of a Tedlar Bag?

The surface of a Tedlar bag is a work in progress. The surface of a new bag is essentially free of VOCs at the single digit ppbv level. Compounds detected from analyzing new Tedlar bags include methylene chloride, toluene, acetone, ethanol, and 2-propanol. Note that 2-propanol has been detected in some new bags up to 45 ppbv. Once the Tedlar bag is used, however, the surface has been exposed to moisture and possibly VOCs. It may irreversibly adsorb many VOCs at the low ppbv level. A series of purges with certified gas will not remove the VOCs from the surface. $15 for a new bag is a small price to pay for peace of mind.

☞ **Never reuse a Tedlar bag when sampling for trace level compounds**

3.1.3 Hold Time for a Tedlar Bag

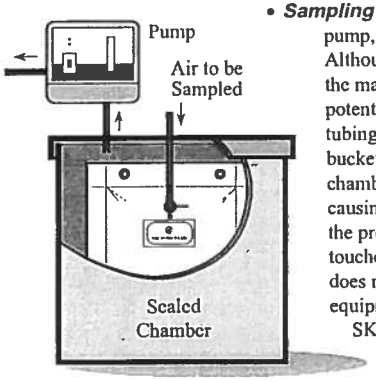
The media hold time for a Tedlar bag is indefinite if stored out of sunlight in a cool, dry location. Tedlar bags can be used to collect samples containing common solvents, hydrocarbons, chlorinated solvents, sulfur compounds, and many other classes of compounds. The sample hold time to analysis varies for different classes of compounds:

- **1 Day**: Sulfur compounds (e.g., hydrogen sulfide and methyl mercaptan) and chemically active compounds (e.g., 1,3-butadiene).
- **3 Days**: Chlorinated solvents, aromatic compounds, and atmospheric/fixed gases (oxygen, nitrogen, carbon dioxide).

3.2 Tedlar Bag Sampling

Using a Tedlar bag to collect an air sample normally involves "active" sampling, unlike an evacuated canister that can be filled "passively" by simply opening the valve. There are two methods commonly used to fill a Tedlar bag: using a pump or a lung sampler.

- ***Sampling with a Pump***: The most common method to fill a Tedlar bag is to use a small pump with low flow rates (50-200 mL/min) and tubing to fill the bag. Air Toxics Ltd. does not provide pumps but they can be rented from equipment providers or purchased from manufacturers such as Neuberger or Gilian.



- ***Sampling with a Lung Sampler***: Alternatively to using a pump, a "lung sampler" can be used to fill a Tedlar bag. Although a little more complicated than simply using a pump, the main advantage to using a lung sampler is that it avoids potential pump contamination. A Tedlar bag with attached tubing is placed in a small airtight chamber (even a 5-gallon bucket can work) with the tubing protruding from the chamber. The sealed chamber is then evacuated with a pump causing the bag to expand and drawing the sample through the protruding tube into the bag. The sample air never touches the wetted surfaces of the pump. Air Toxics Ltd. does not provide lung samplers, but they can be rented from equipment suppliers or purchased by manufacturers such as SKC Inc.

3.2.1 Considerations for Tedlar Bag Sampling

The following are some considerations for collecting a Tedlar bag sample.

- **Fill the Tedlar bag no more than 2/3 full**: Allow for possible expansion due to an increase in temperature or decrease in atmospheric pressure (e.g., the cargo hold of a plane).
- **Keep the Tedlar bag out of sunlight**: Tedlar film is transparent to ultraviolet light (although opaque versions are available) and the sample should be kept out of sunlight to avoid any photo-chemical reactions.
- **Protect the Tedlar bag**: Store and ship the Tedlar bag samples in a protective box at room temperature. An ice chest can be used, but DO NOT CHILL.
- **Fill out the Tedlar bag label**: It is much easier to write the sample information on the label before the Tedlar bag is inflated.
- **Provide a second Tedlar bag**: Consider filling two bags per location in the rare occasion that a defective bag deflates before analysis.
- **Avoid Contamination**: Care should be taken to avoid contamination introduced by the pump or tubing. Begin sampling at locations with the lowest compound concentrations (e.g., sample the SVE effluent before the influent). Decontaminate the pump between uses by purging with certified air for an extended period; better yet, use a lung sampler. Use shortest length possible of Teflon tubing or other inert tubing. Do not reuse tubing. If long lengths of tubing are used, consider purging the tubing with several volumes worth before sampling. If you are concerned about sampling for trace compounds, you shouldn't be using a Tedlar bag (see Section 1.2).
- **Don't Sample Dangerous Compounds in a Tedlar Bag**: Do not ship any explosive substances, radiological or biological agents, corrosives, or extremely hazardous materials to Air Toxics Ltd. Tedlar bag rupture during transit to the laboratory is possible and the sampler assumes full liability.

3.2.2 Step-by-Step Procedures for Tedlar Bag Sampling (Pump)

Note: These procedures are for a typical stationary source (e.g., SVE system) sampling application; actual field conditions and procedures may vary. See additional sampling considerations in Section 4.3 for sampling soil gas or landfill gas.

Before you get to the field:

1. Verify contents of the shipped package (e.g., chain-of-custody, Tedlar bag, and tubing/fittings – if requested)
2. Verify pump cleanliness and operation (Air Toxics Ltd. does not provide pumps)

When ready to sample:

3. Purge sample port
4. Attach new Teflon tubing from sample port or probe to low flow rate pump
5. Purge tubing
6. Fill out Tedlar bag sample tag
7. Attach additional new Teflon tubing from the pump outlet to the Tedlar bag valve
8. Open Tedlar bag valve
9. Collect sample (FILL NO MORE THAN 2/3 FULL)
10. Close Tedlar bag valve by hand tightening valve clockwise
11. Return Tedlar bag in boxes provided (DO NOT CHILL)
12. Fill out chain-of-custody and relinquish samples properly
13. Place chain-of-custody in box and retain pink copy
14. Tape box shut and affix custody seal (if applicable) across flap
15. Ship priority overnight to meet method holding times. 3 DAY HOLD TIME TO ANALYSIS (most analyses)

Section 4. Special Sampling Considerations

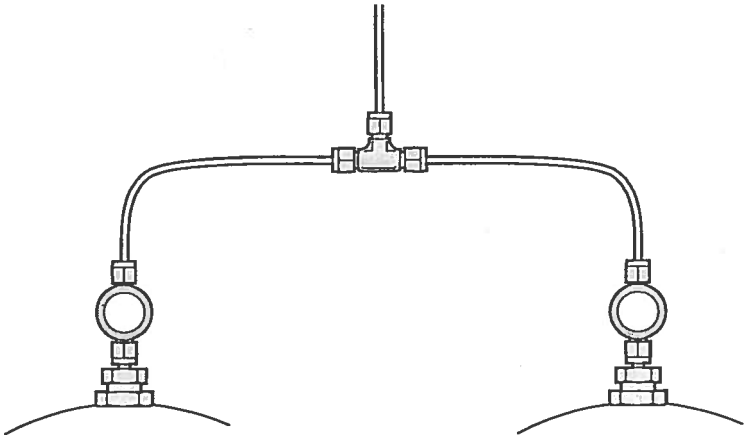
This section provides considerations for special sampling configurations that a sampler may collect in the field such as a field duplicates or an ambient blank. This section also provides considerations for sampling at altitude, soil/landfill gas sampling, and sample cylinder sampling.

4.1 Special Sampling Configurations

Special sampling configurations include a field duplicate, field split, field blank, ambient blank, trip blank, and an equipment rinse. Call Client Services at 800-985-5955 if your project involves any of these special sampling configurations.

4.1.1 Field Duplicate

A field duplicate is a second sample collected in the field simultaneously with the primary sample at one sampling location. The results of the duplicate sample can be compared (e.g., calculate relative percent difference) with the primary sample to provide information on consistency and reproducibility of field sampling procedures. Due to the nature of the gas phase, duplicate samples should be collected from a common inlet. The configuration for collecting a field duplicate includes stainless steel or Teflon tubing connected to a Swagelock "tee". It is imperative that individually certified (i.e., 100% certification process) canisters be used to collect a field duplicate.



assumes that clients requesting a sample cylinder have a pressurized process and sample port with a built-in gauge and 1/4 in. Swagelock fitting to attach to the sample cylinder. Air Toxics Ltd. has an inventory of 500 mL sample cylinders that are particularly suited for landfill gas collection systems (i.e., LFG to energy applications). This section provides step-by-step procedures for sampling with a sample cylinder.

Step-by-Step Procedures for Sample Cylinder Sampling

These procedures are for a typical stationary source sampling application and actual field conditions and procedures may vary. Follow all precautions in the site Health and Safety Plan when dealing with a pressurized sample port and sample cylinder.

1. Verify contents of the shipped package (e.g., chain-of-custody, sample cylinder, particulate filter)
2. Verify that gauge on sample port is working properly
3. Purge sample port
4. Remove brass caps on either end of cylinder
5. Attach particulate filter to upstream valve
6. Attach filter/cylinder assembly directly to the sample port
7. Open both valves 1/2 turn
8. Allow sample air to flow through sample cylinder (approximately 10 L for a 500 mL cylinder)
9. Close downstream valve of sample cylinder by hand tightening knob clockwise
10. Allow sample cylinder to pressurize to process pressure (max 100 psig)
11. Close upstream valve of sample cylinder and sample port
12. Detach filter/cylinder assembly from sample port and remove particulate filter
13. Replace brass caps
14. Fill out sample cylinder sample tag
15. Return sample cylinder in box provided
    - Unreturned sample cylinder charge of $650 each.
16. Return sample media in packaging provided. Unreturned equipment charges:
    - $45 per particulate filter
17. Fill out chain-of-custody and relinquish samples properly
18. Place chain-of-custody in box and retain pink copy
19. Tape box shut and affix custody seal (if applicable) across flap
20. Ship accordingly to meet method holding times

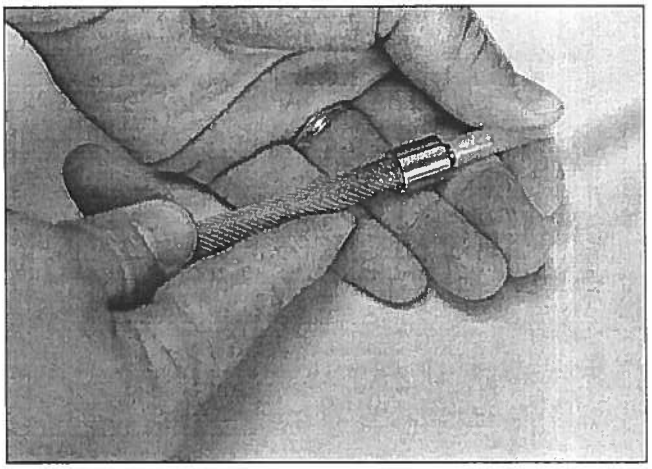
Appendix B

Geoprobe® Sampling Implant Operation

Implants Operation

from Geoprobe Systems®

www.geoprobe.com
1-800-436-7762



Attaching polyethylene tubing to the sampling implant.

Sampling Implants – Operation

Installation Instructions for Soil Gas Implants

1. Drive probe rods to the desired depth using a Point Holder (AT-13B) and an Implant Anchor/Drive Point (PR-14). DO NOT disengage the drive point when depth has been reached.

2. Attach appropriate tubing to the implant (**Figure 1**). If tubing is pre-cut, allow it to be approximately 48 in. (1219 mm) longer than the required depth of the implant. Cover or plug the open end of the tubing.

3. Remove pull cap and lower the implant and tubing down inside the diameter of the probe rods until the implant hits the top of the Anchor/Drive Point. Note the length of the tubing to assure that proper depth has been reached.

4. Rotate tubing counterclockwise while exerting a gentle downward force to engage the PRT threads (**Figure 2**). Pull up on the tubing lightly to test the connection. DO NOT cut excess tubing.

5. Position a Probe Rod Pull Plate or Manual Probe Rod Jack on the top probe rod. Exert downward pressure on the tubing while pulling the probe rods up. Pull up about 12 in. (305 mm).

6. If using 1/4-in. (6,4 mm) O.D. tubing or smaller, thread the excess tubing through the Implant Funnel and position it over the top probe rod. If using larger tubing, it may not be possible to install the glass beads.

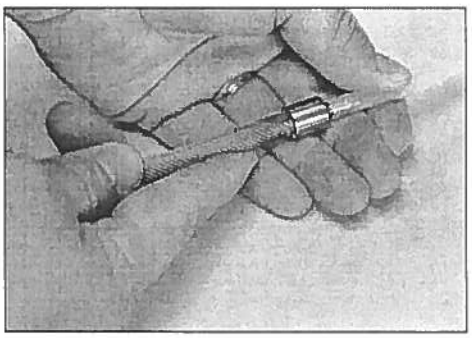


Figure 1. Attaching tubing to the sampling implant.

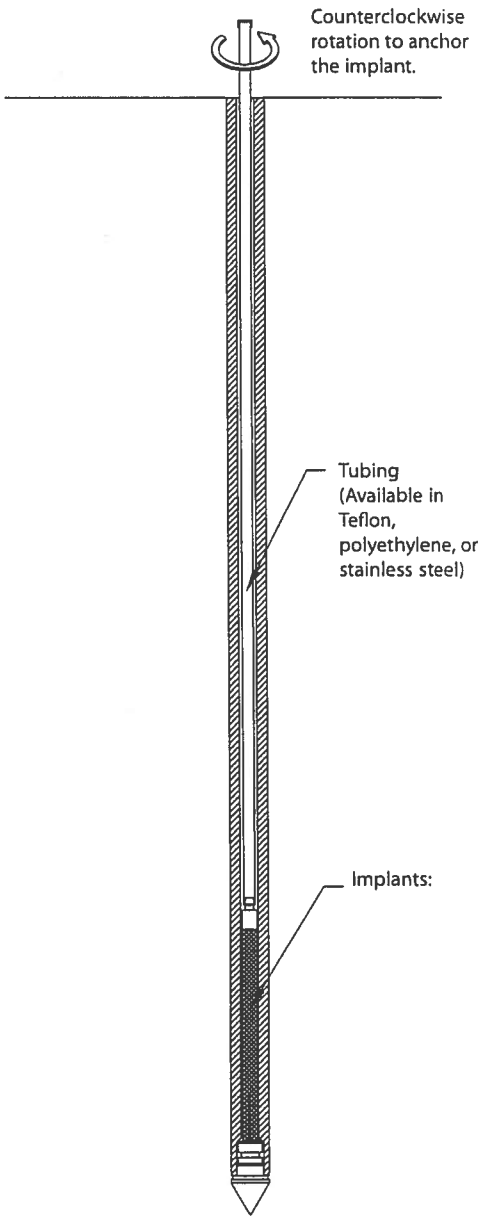


Figure 2. Once depth is achieved, the selected implant and tubing are inserted through the rods. The tubing is rotated to lock the implant into the drive point.

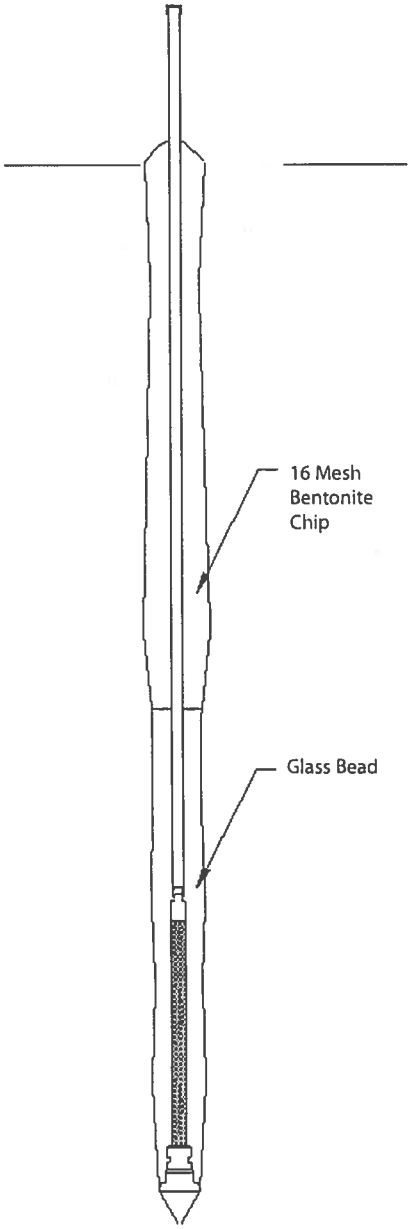


Figure 4. After the implant has been secured, the rods are removed and the annulus backfilled as appropriate.

7. Pour glass beads down the inside diameter of the probe rods around the outside of the tubing. Use the tubing to "stir" the glass beads into place around the implant. Do not lift up on tubing. It should take less than 150 mL of glass beads to fill the space around the implant.

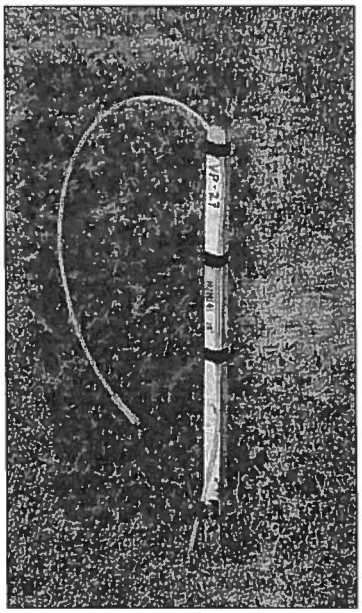
   NOTE: Backfilling through the rods with glass beads or glass beads/bentonite mixes can only be performed in the Vadose Zone, not below the water table.

8. Lift up an additional 18 to 24 in. (457 to 610 mm) and pour the bentonite seal mixture into place as in Step 7. The volume to be filled is about 154 mL per foot. It may be necessary to "chase" the seal mixture with distilled water to initiate the seal.

9. Pull the remaining rods out of the hole as in Step 5. Backfilling with sackcrete (cement/sand) or bentonite/sand may be done while removing the rods (**Figure 4**). If the PR-14 Implant Anchor is used, the tubing may be cut flush with the top probe rod and a regular pull cap may be used to remove the remaining probe rods after Step 8.

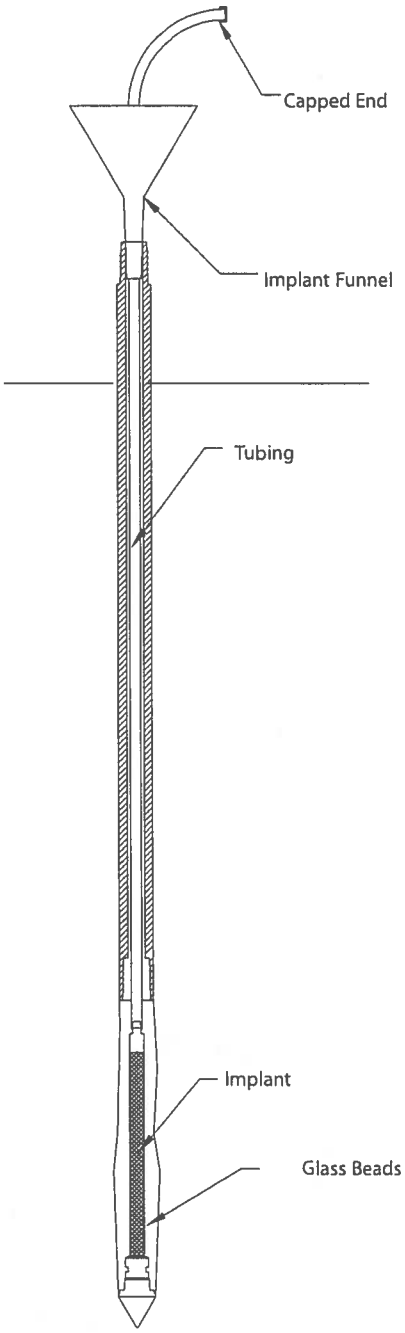
10. After the probe rods have been removed, cut the tubing at the surface, attach a connector or plug, and mark the location with a pin flag or stake. The point is ready for sampling now.

Figure 3. Glass Beads create a permeable layer around vapor sample implants.

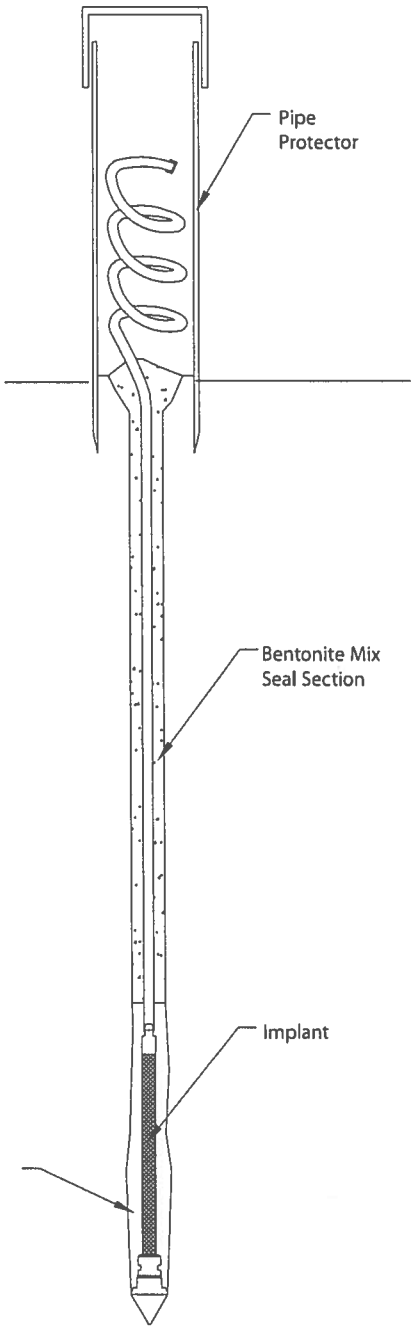


A vapor implant location.

Sampling Implants – Operation



Backfill materials include glass beads and bentonite sealants.



Example of completed permanent soil gas monitoring point.